CNS Emergencies: Trauma

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CNS TRAUMA

- Impact or Direct Injury
  - CONTACT Injury
  - Scalp/skull Abnormal
- Inertial or Indirect Injury
  - NON-CONTACT Injury
  - Acceleration/deceleration
  - Scalp/skull Normal

Learning to Care for Those in Harm's Way

Types of Injury

- Primary Brain Lesions
  - Contusions
  - Shearing Injury
  - Immediate neurologic problem
- Secondary Brain Lesions
  - Mass Effect
  - Increased ICP
  - Herniation
  - Infarction
  - Variable Delay in Sx

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Trauma Pathophysiology Matrix

	Non-Contact	Impact
Primary Injury to Brain	DAI/DWI (Axonal injury)	Contusion: •Coup •Contre-Coup Axonal injury
Secondary Injury to Brain	Subdural Hematoma	Epidural Hematoma Subdural Hematoma

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Causes of Head Trauma

- Motor Vehicle Accidents
  - 50%
- Falls from a height
  - 10 - 20%
- Accidental
- Non-accidental (e.g. Child Abuse)
- Workplace
- Recreational

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Roller Coaster Headache

- Roller Coasters can create 2.5 – 3.5 G's
- Grandpa rides with Grandaughter
  - She's screaming with excitement
  - **He's subdued by a Subdural Hematoma**

Reference:
Fukutake T, Mine S, Yamakami I, Yamaura A, Hattori T.
Roller coaster headache and subdural hematoma.
Neurology. 2000 Jan 11;54(1):264.
PMID: 10636168; UI: 20100123

Prague to Vienna – 19 June 2004

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Hydroplaning Accident

- 9 passenger van
- All belted in
- 180 direction turn
- 2-1/2 turn barrel rollover
- No one blacked out
- Everyone walked away
- **Should we have been scanned?**

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Indications for Imaging

- Acute Neurologic Deficit
- Observed L. O. C.
- Persistent HA
- Severe Trauma
- Obvious Injury

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Normal GCS w/Minor Head Trauma

"CT can be safely limited to those who have …"

- Headache
- Vomiting
- Age > 60 yrs
- Drug or EtOH intoxication
- Physical signs of trauma above clavicles
- Seizures

NEJM 2000;34: 100-1005

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Patient Preparation

- Stable vital signs ?
- Intact Cx spine ?
  - Screening plain films
  - Immobilize neck
- Type of Exam
  - CT w/o Contrast
  - MR standard
  - MR special
  - Nuclear Medicine

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Acute CNS Imaging: Results

- NCT
  - Mass Effect, Herniation, Shift
  - Blood, Edema, Ca ++
- ECT
  - Contusions, Infarcts
  - Infection, Inflammation
  - Tumors, AVM's
- MR
  - Mass Effect, Herniation, Shift
  - **MSI** or GRE (Gradient Refocused) for **Blood**
  - FLAIR & Diffusion Imaging for Shearing and Contusion injury

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Relative Sensitivity

Higher

- MR Spectroscopy (decreased NAA)
- Magnetization Transfer Ratio
- Magnetic Susceptibility (MSI or GRE)
- Apparent Diffusion Coefficient
- Diffusion Weighted Imaging
- FLAIR
- Convention SE MR (T2W > T1W)
- **CT (ECT > NCT)**
- Skull Radiogram

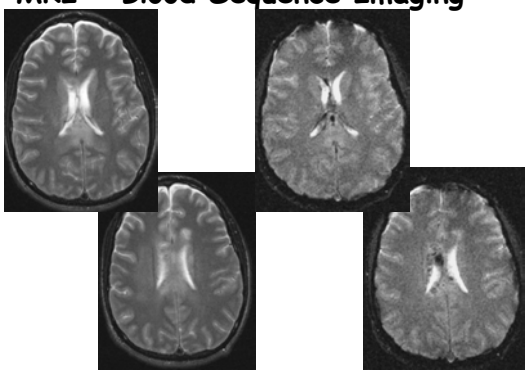
Lower

3 Reasons for Getting an MR

- CT fails to explain Pt's Condition
- CT fails to explain Pt's Condition
- CT fails to explain Pt's Condition

Hospitalized patients need further evaluation with MR

MRI - Blood Sequence Imaging



Animal Head Trauma

- Head Bangers
  - Wapiti
  - Elephants
- Woodpeckers
  - A fibrocartilage "cushion" on beak

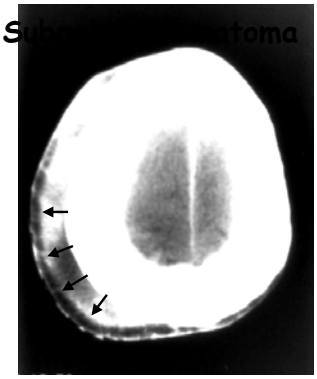
CENTRIPETAL APPROACH

(outside to inside)

- SCALP
- CALVARIUM
- EPIDURAL
- SUBDURAL
- SUBARACHNOID
- INTRA-PARENCHYMAL
- INTRA-VENTRICULAR

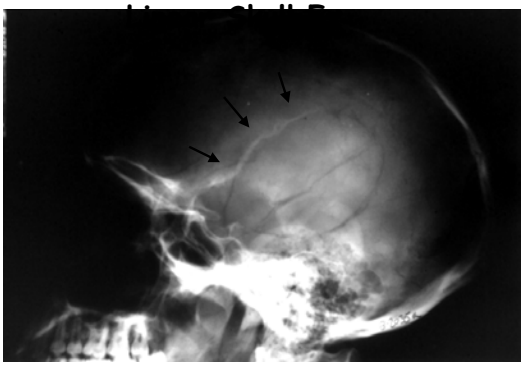
CNS TRAUMA -- SUBGALEAL

- Between periosteum of OUTER table and the GALEA (under scalp fat)
- In CHILD, significant blood loss
- Spontaneous decompression of intracranial (Epidural) hematoma

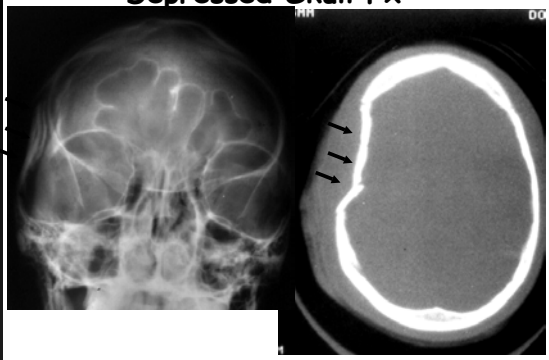


Skull Fractures

- Linear
- Stellate
- Depressed
- Basilar
- Eggshell



Depressed Skull Fx



Basilar Skull Fracture

- RHINORRHEA (CSF)
- OTORRHEA (CSF / Hemotympanum)
- PNEUMOCEPHALUS
  - air in sulci
  - air and fluid/levels in sinuses
- RACCOON EYES
  - periorbital ecchymoses
- BATTLE'S SIGN
  - Retroauricular ecchymoses

BASILAR SKULL Fx:

- CSF LEAK
  - Infection
  - Pneumocephalus
- CNN. INJURY
  - Deficit Acute or Delayed
- VASCULAR TRAUMA
  - Laceration or dissection
  - Occlusion & infarction
  - FISTULAE (C-C)

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TEMPORAL BONE Fx

- Longitudinal
  - most common (70-90%)
  - parallel to petrous ridge
  - CSF oto-/rhino-rrhea (conductive hearing loss)
  - facial (VII n.) (10-20%)
- Transverse, less common (10-30%)
  - perpendicular to petrous ridge
  - labyrinth/cochlear destruction
  - sensorineural (VIII - both parts)
  - facial (VII n.) (40-50%)

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Blow-Out Fx

- Blunt force trauma (e.g. Ball or fist)
- Hydraulic (pressure) forces increased intra-orbital pressure
- Fractures thin bones
  - Floor (orbital process of maxilla)
  - Medial (20-50%) (lacrimal and ethmoid)
- Herniation and entrapment
  - orbital fat & EOM (inf. Oblique)

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Healing Skull Fracture

- INFANTS:
  - 3-6 mo.. (without a trace!)
- CHILDREN (5-12 yrs):
  - 12 mo.
- ADULTS:
  - 2-3 yrs. (persistent lucency,mimics vascular groove)
  - "Growing" fracture
  - Leptomeningeal cyst
  - Herniation of SAS (w/CSF) through Fx
  - Pulsation erodes bone

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MEMBRANE HEMATOMAS:

- Subgaleal
- Subperiosteal Outer Table
  - Cephalohematoma
- Subperiosteal Inner Table
  - Epi (Extra) Dural
- Subdural
  - 'Epi-arachnoid'
- Subarachnoid ***
- Parenchymal Hematoma
- Intra-ventricular

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Learning to Care for Those in Harm's Way

EPIDURAL HEMATOMA

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CNS TRAUMA EPIDURAL HEMATOMA

- **Young Men (20-40's)**
  - Head Trauma frequent
  - Also, dura (periosteum) more adherent in older people
- Acute presentation
- Skull fracture (90%)
- Bi-convex, hyperdense- limited by sutures

EPIDURAL HEMATOMA Source of Bleeding

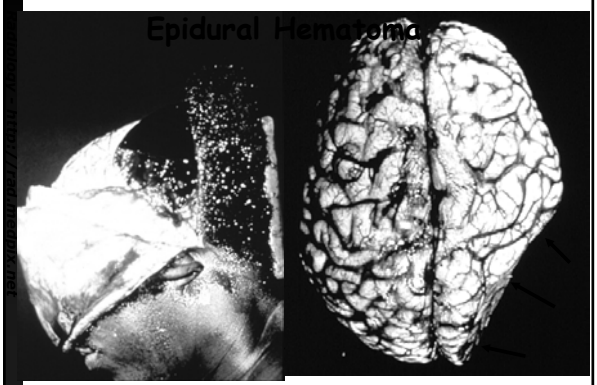
- MENINGEAL VESSELS
  - **Arterial (high pressure)**
  - Venous (low pressure)
- DURAL SINUS
  - High flow, low pressure
- OTHER
  - Diploic veins (Fx)
  - Marrow sinusoids

EPIDURAL HEMATOMA

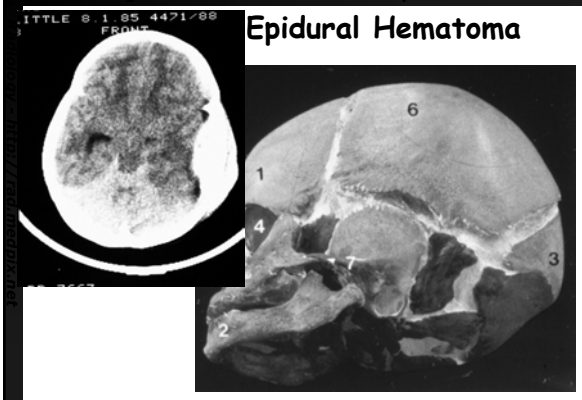
- Significant trauma
- Fracture & concussion (l.o.c.)
- **Lucid Interval**
  - **Pt Wakes Up**
  - **40% pts.**
- Delayed neurologic Sx (hrs. Later)
- Herniation, coma and death

EPIDURAL HEMATOMA

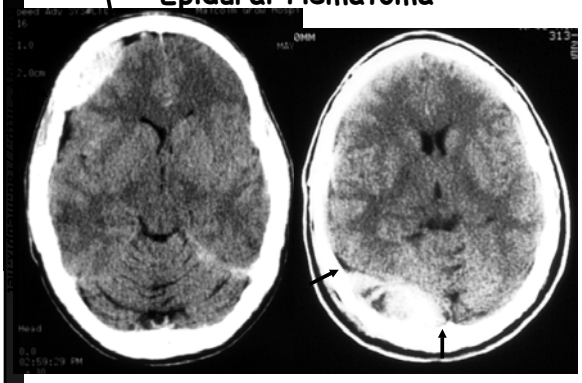
- Trauma -> fracture & concussion
- Tearing/stripping of both layers from inner table
- Laceration of outer periosteal layer
- Laceration of meningeal vessels
- Inner (meningeal dura) intact
- Blood between naked bone and dura
- **NORMAL arterial pressure continues to dissect**



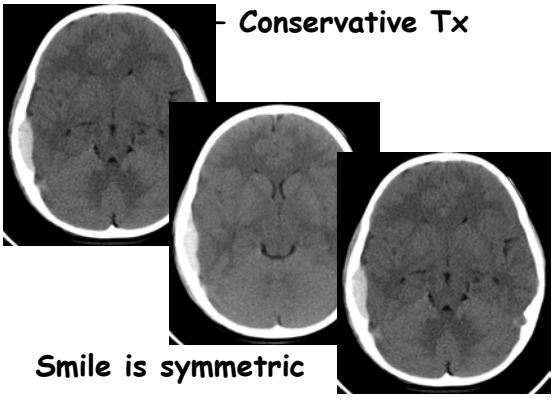
Epidural Hematoma



Epidural Hematoma

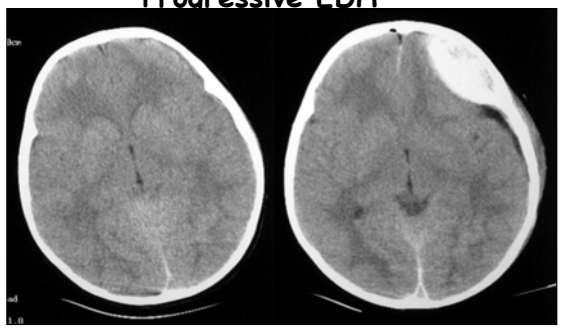


Conservative Tx



Smile is symmetric

Progressive EDH



10 AM **8 PM**

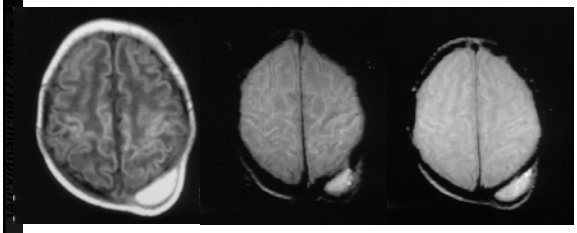
Epidural Hematoma - Treatment

- Craniotomy
- Drain clot
- Repair the Artery!

SUBPERIOSTEAL HEMATOMA

- CEPHALOHEMATOMA
  - (Birth trauma)
  - (outer table, sub-periosteal)
- EPIDURAL HEMATOMA
  - (Inner table, "sub-periosteal")

Cephalohematoma
Birth Trauma



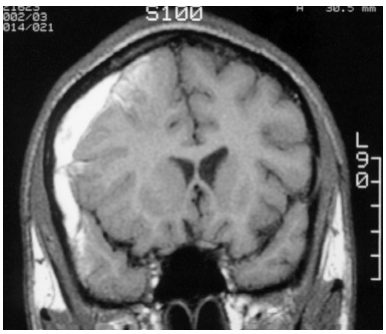
SUBDURAL HEMATOMA

- Extremes of age
  - Infants/elderly
- Subacute presentation
  - Days or weeks after trauma
- Fracture not needed
- Crescentic
  - Not hyperdense
  - Crosses sutures commonly
  - Interhemispheric fissure (kids)
- Epi - Arachnoid

SUBDURAL HEMATOMA - Source of Blood

- Laceration Of Cortical Aa. and Vv.
  - Direct: Penetrating Injury
- Large Contusions
  - Direct/indirect: "Pulped Brain"
- Torn Bridging (Cortical) Veins
  - Indirect
  - Acceleration-deceleration

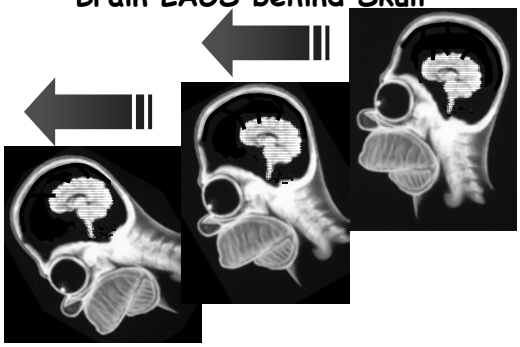
Subdural Hematoma



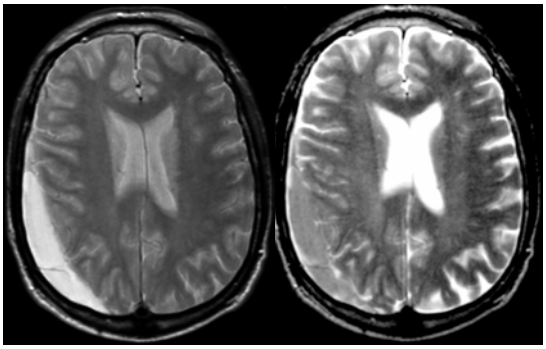
SUBDURAL HEMATOMA

- Acceleration-deceleration
- Sagittal Plane
  - Causes Oscillation Of Brain
  - Brain LAGS Behind Skull
- Bridging Veins Stretch & Tear
  - **Venous Bleeding (Slow)**
  - **Multiple and Bilateral Veins**
- Dissection Of Subdural Space
  - Under Dura - Over Arachnoid
  - Spreads around convexity
  - Into the interhemispheric fissure (child)

Brain LAGS behind Skull



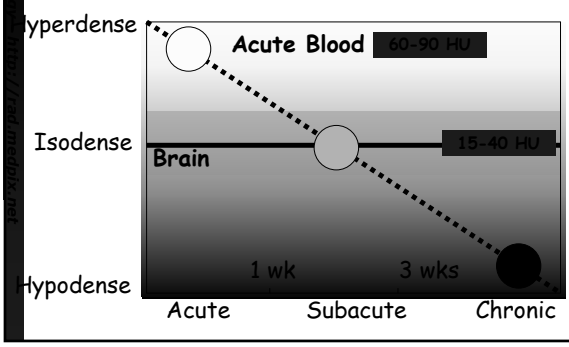
Acute and Hyperdense SDH



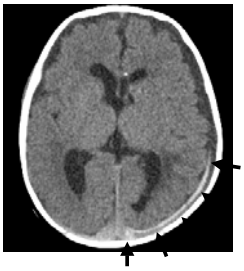
SUBDURAL HEMATOMA

- ACUTE (0-7 days)
  - HYPERDENSE (65-90 Hu)
- SUBACUTE (7-22 days)
  - ISODENSE (20-40 Hu)
- CHRONIC (>22 days)
  - HYPODENSE (0-20 Hu)

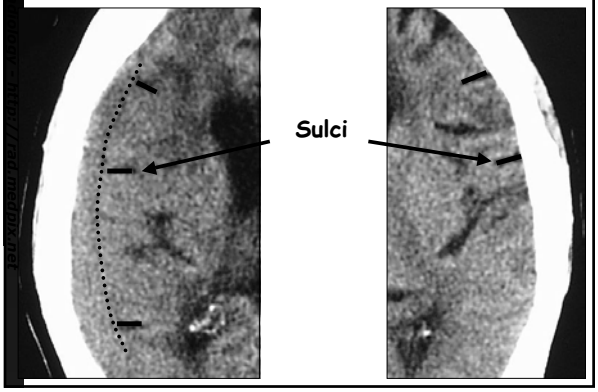
Hemorrhage: Change over time



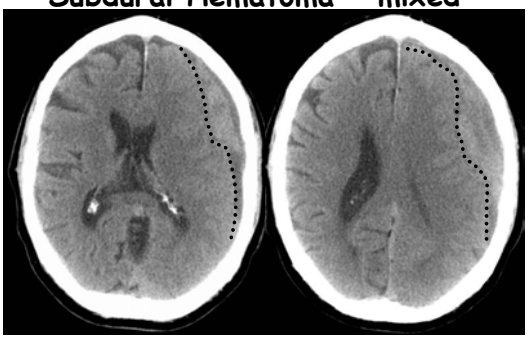
Subdural Hematoma - Child Abuse



Isodense subdural



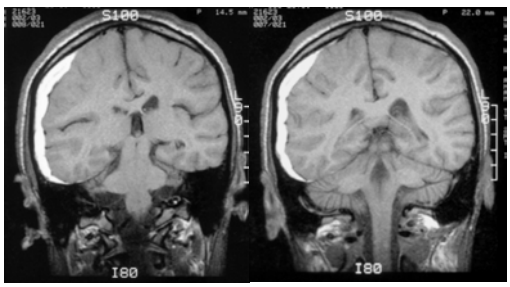
Subdural Hematoma - mixed



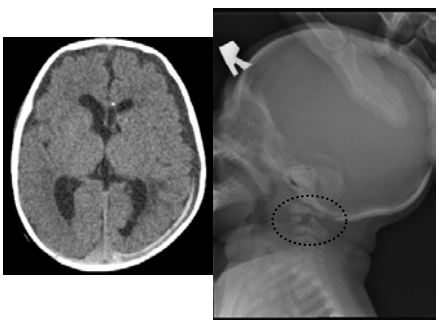
SUBDURAL COLLECTIONS

- Acute SDH - hyperdense
- Subacute SDH - isodense
- Chronic SDH - hypodense
- Hygromas
  - Hypodense, isointense to CSF
  - CSF leak from arachnoid tears
- Effusions
  - Hypodense(meningo-encephalitis, esp. H.flu)

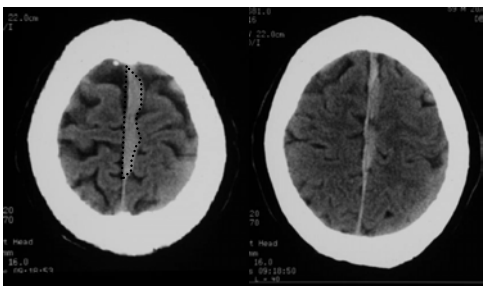
Subdural Hematoma



Child Abuse?



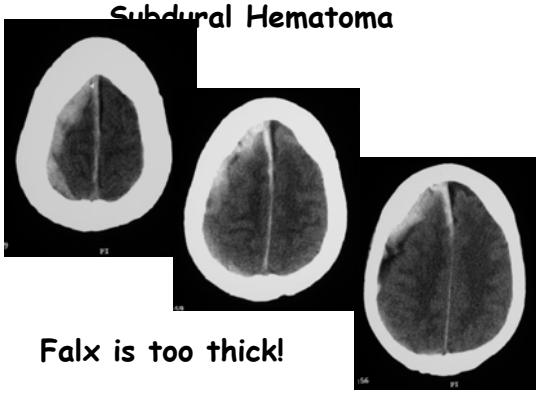
Interhemispheric Subdural



INTERHEMISPHERIC FISSURE and the FALX SIGN

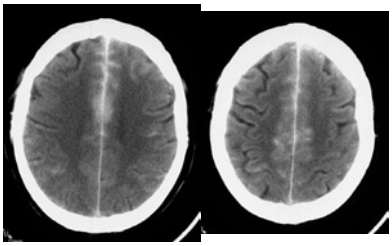
- Normal Falx:
  - thin white line, may see CSF parallel
- Subarachnoid Blood:
  - anterior, zig-zag, reaches the corpus
- Subdural Hematoma:
  - posterior, straight, doesn't touch the corpus callosum

Subdural Hematoma



Falx is too thick!

Subarachnoid Hemorrhage

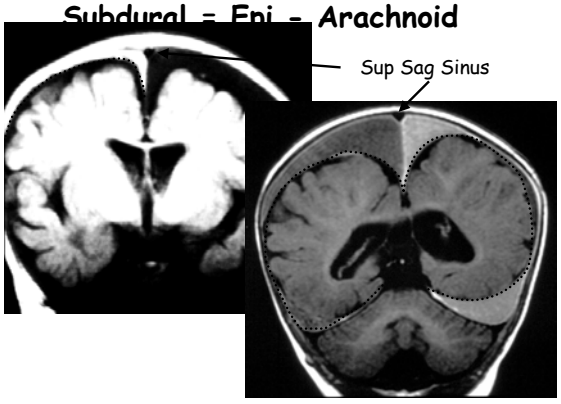


Zig-Zag into Sulci

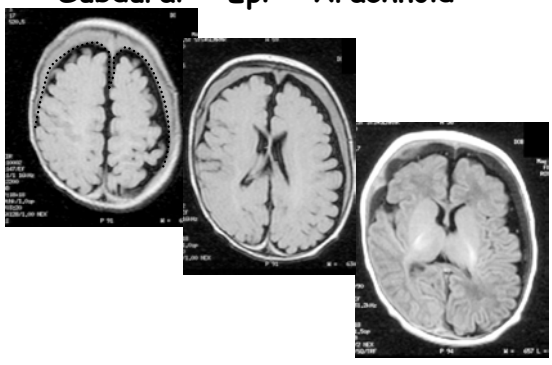
Child Abuse

- The "Multiple Sclerosis" of trauma:
  - Lesions separated in space
  - Lesions separated in time
- Ophthalmoscope Exam Required
  - Retinal hemorrhage highly correlated with non-accidental trauma
- Skeletal survey?

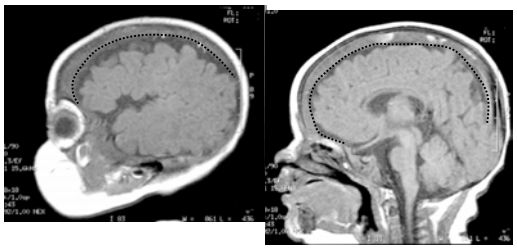
Subdural = Epi - Arachnoid



Subdural = Epi - Arachnoid



Subdural = Epi - Arachnoid



MAGNETIC RESONANCE
Imaging of Hemorrhage

Blood Product	T1W	T2W
Oxyhemoglobin	Iso	Iso
De-oxy Hgb	Iso (1-3hrs)	Low (2hrs)
Met-Hgb (in cells)	Hi (3-14hr)	Low
Met-Hgb (in soln.)	Hi	Hi (hrs-wks)
Hemichromes	Low	Low
Hemosiderin	Low	Lower

Subdural Hematoma

- ISOLATED SDH:
  - Infants/Elderly
  - Subacute/Chronic
  - Presentation w/Mild Deficit
- COMPLICATED SDH:
  - Middle Age
  - Acute Presentation
  - Complex Injuries (Incl. DAI, etc.)

Cerebral Contusion

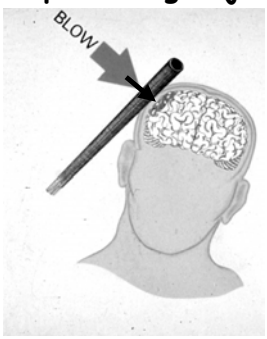
CEREBRAL CONTUSION

- Traumatic/mechanical disruption of small (capillary) vessels
- Extravasation of whole blood, plasma (edema) and RBC's
- Admixture of blood mixed with native tissue (petechial hemorrhage)
- Mottled / speckled density ("salt and pepper" on CT)

CEREBRAL CONTUSION
naming conventions

- COUP (SAME SIDE AS IMPACT)
  - (w/fractures, small area of impact)
- INTERMEDIATE (CENTRAL)
  - (DAI/Shearing Injury)
- CONTRE - COUP (OPPOSITE IMPACT)
  - (w/falls, broad surface of impact)

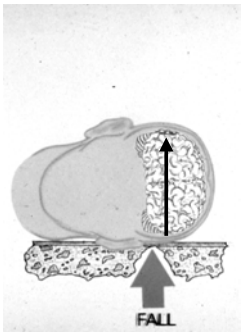
Coup: Moving object strikes head



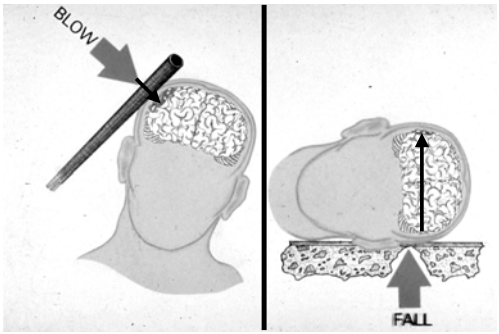
Forces transmitted directly through skull to underlying brain cortex

Contrecoup: Moving head strikes object

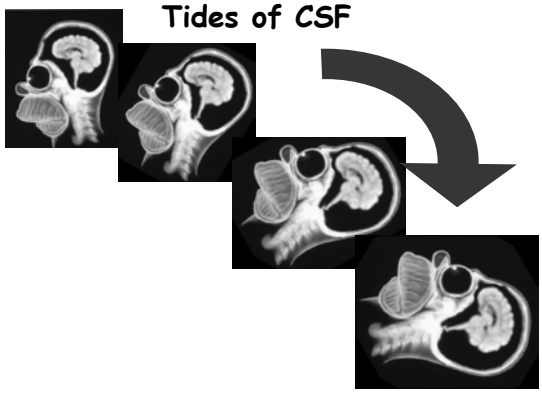
Moving head strikes the ground - a broad flat surface, forces indirectly transmitted to brain.



Coup vs. Contrecoup



Tides of CSF



Pressure Waves

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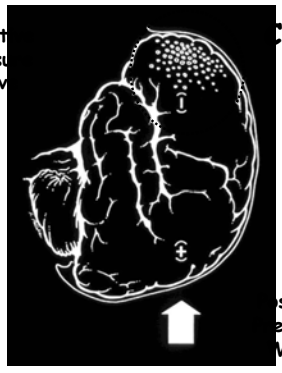

Cavitation

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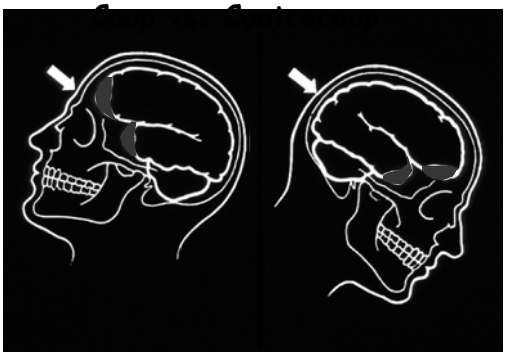
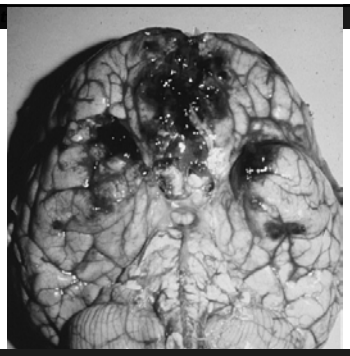
Wave



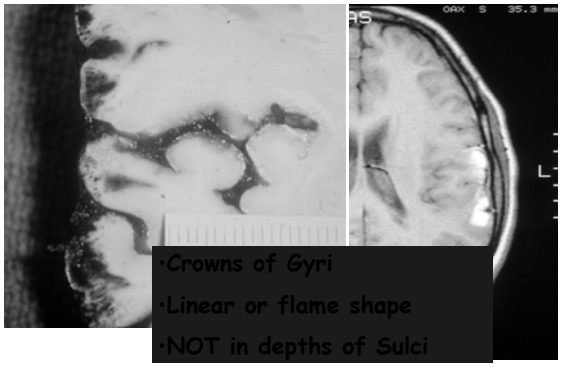
CEREBRAL CONTUSION

- MECHANICAL INJURY TO VESSELS
  - Extravasation of whole blood
- PETECHIAL / PERIVASCULAR HEMORRHAGE
  - Admixture of tissue and blood
  - average density may NOT be high
- SWELLING/MASS EFFECT
- MAY PROGRESS TO HEMATOMA
  - If larger vessels are damaged
  - large confluent mass of blood



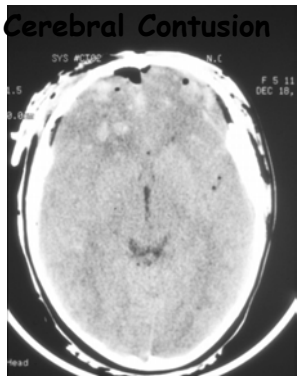
Temporal Tips
Orbitofrontal Gyri

Cerebral Cortical Contusion

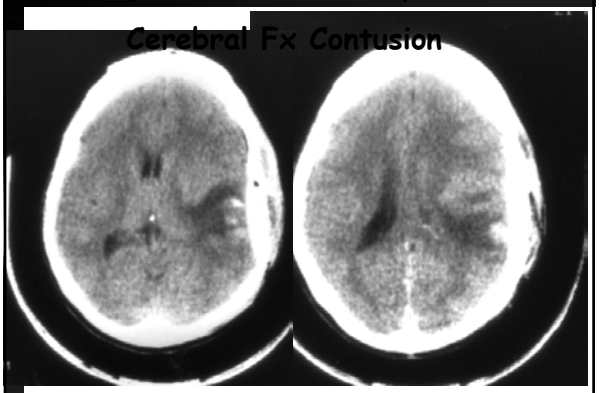


- Crowns of Gyri
- Linear or flame shape
- NOT in depths of Sulci

Cerebral Contusion



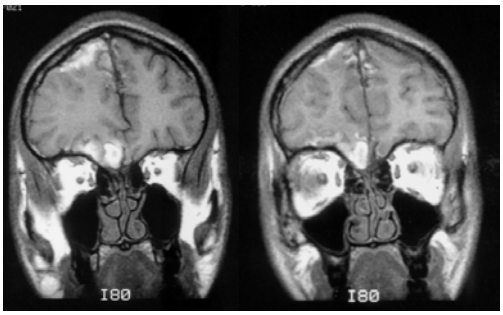
Cerebral Fx Contusion



CEREBRAL CONTUSION

- CT Hypodense (EDEMA)
  - Isodense (mass)
  - Hyperdense(mottled, speckled)
- MR Variable Intensity
  - (GRE) - Hypointense
  - Hyperacute Blood
- COUP CONTUSION
  - ASSOCIATED w/Fx

Cerebral Contusion



SHEARING INJURIES

- **Deep lesions**
- High Velocity (MVA) Trauma
- Acceleration/Deceleration
  - Especially CORONAL angular momentum
  - Side Impact (Running a Red Light)
- Do not require an impact or Fx.
- **"SHEARING OF AXONS"**
  - Breaks connections
  - Actual force may be tension
- "SHEARING" of Small WM VESSELS
  - Small (petechial) hemorrhages

Deep Lesions – Coronal Forces

Angular momentum in the Coronal Plane:
Running a Red Light … T-Bone the cars

Deep Lesions - Terminology

- Intermediate Contusions
- Shearing Injury
- Diffuse White-matter Injury (DWI)
- **Diffuse Axonal Injury (DAI)**

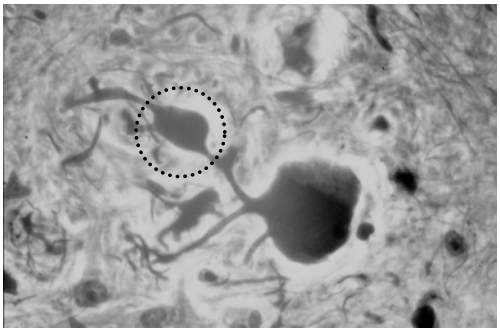
DWI/DAI = Deep Lesions

- <15mm diameter and BELOW cortex
- Subcortical and Hemispheric WM
- Corpus Callosum
  - posterior body
  - splenium
- Brain stem
  - Dorsolateral Quadrant of Upper BS
  - Deep BS
  - Ventral BS

DIFFUSE AXONAL INJURY

- Neurologic Sx Begin at Impact
- Some have Immediate L.O.C.
- Some have Persistent Vegetative State
- Pathology:
  - foci of hemorrhage in callosum, brainstem, etc.
  - axon retraction balls (ARB)
- Long-Term Survivors:
  - microglial clusters
  - foci of demyelination

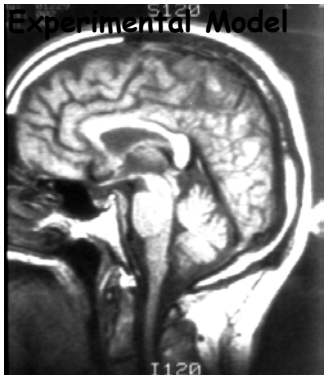
Axon Retraction Balls



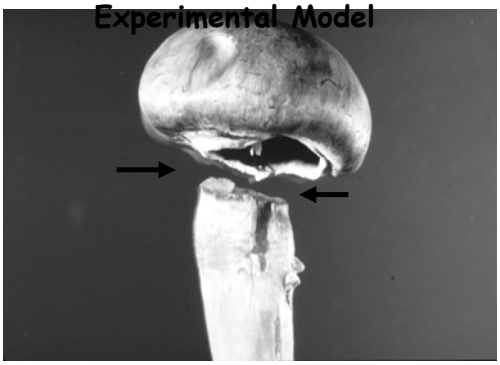
DAI or DWI

- Non limited to White Matter
  - Basal Ganglia and Thalamus
- Some patients in "Coma"
  - Different types of "Coma"
  - Global lesions
  - Small focal lesions (e.g. Reticular formation
- Some have subtle changes on specialized psychometric tests

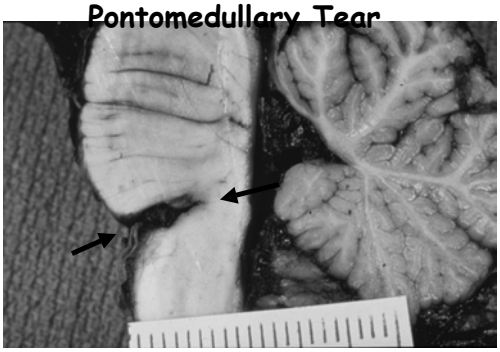
Experimental Model



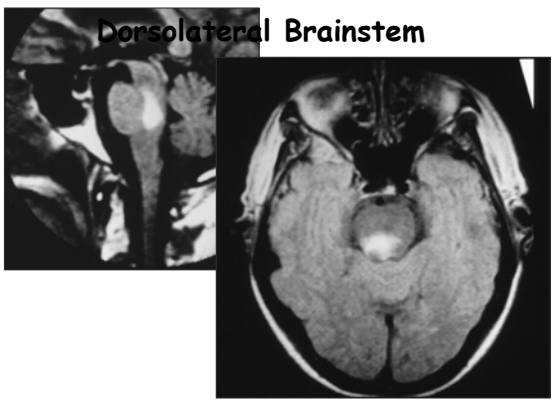
Experimental Model



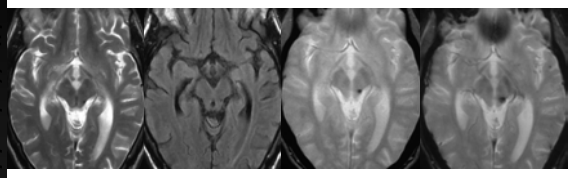
Pontomedullary Tear



Dorsolateral Brainstem



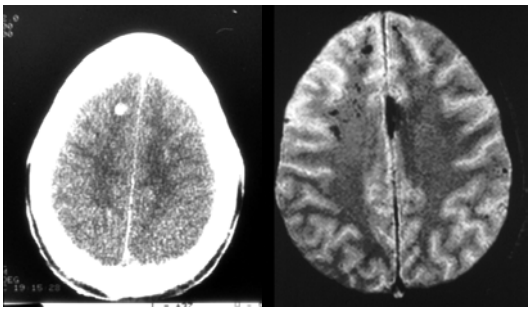
Diffuse axonal injury (Magnetic Susceptibility)



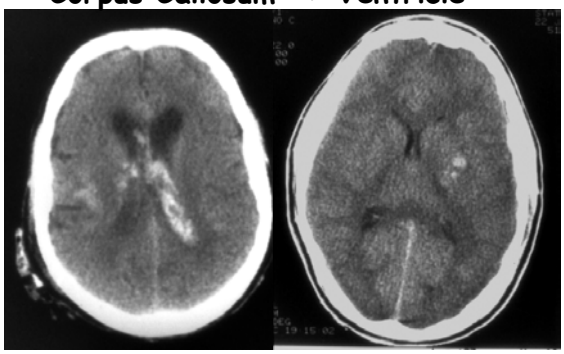
TSE T2 | Turbo FLAIR | FLASH T2* TE: 15 ms | FLASH T2* TE: 35 ms

*Ref. Parizel PM et al. Eur. Radiol. **1998**; 8: 960-965*

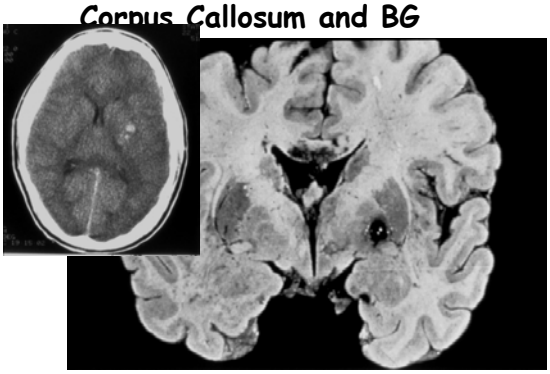
CT vs. MR (GRE)



Corpus Callosum -> Ventricle

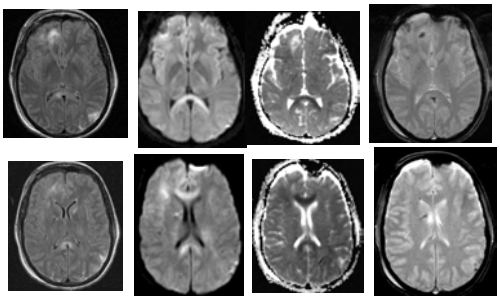


Corpus Callosum and BG



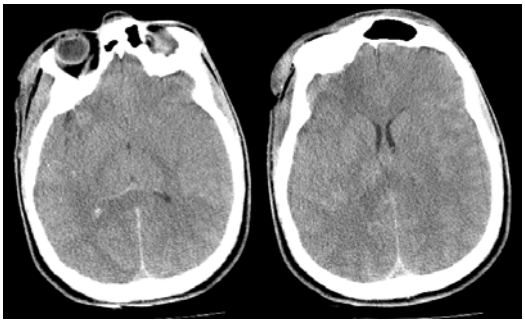
Diffuse White-Matter Injury

FLAIR | DWI | ADC | MSI



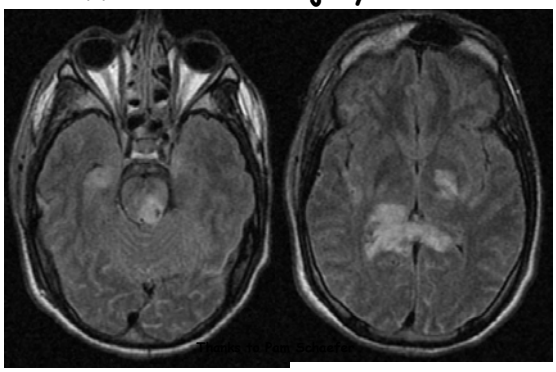
Thanks to Pam Schaefer, MGH

Unconscious Patient - CT



Thanks to Pam Schaefer

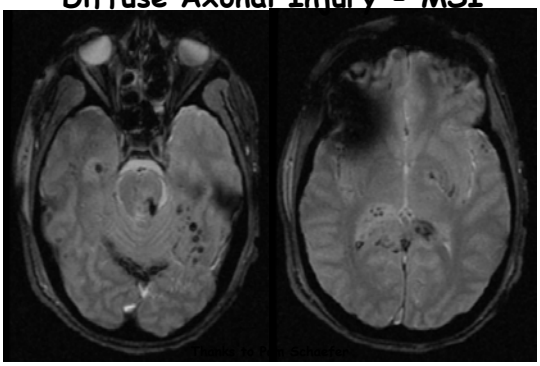
Diffuse Axonal Injury - FLAIR



Thanks to Pam Schaefer

Learning to Care for Those in Harm's Way

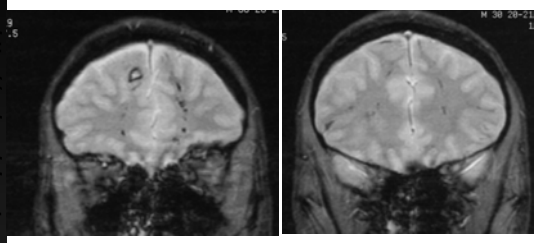
Diffuse Axonal Injury - MSI



Thanks to Pam Schaefer

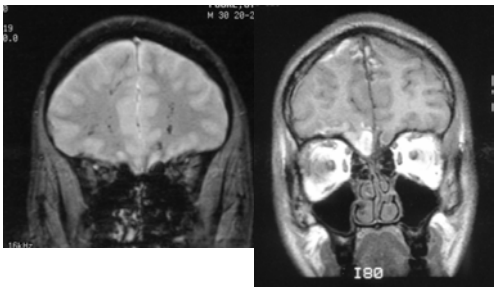
Learning to Care for Those in Harm's Way

Shearing Injury - Deep Lesions



Learning to Care for Those in Harm's Way

Shearing Injury vs. Contusion



Contusions are surface lesions

Learning to Care for Those in Harm's Way

CNS TRAUMA - Summary

- Epidural Hematoma (subperiosteal)
  - acute, convex, white
- Subdural hematoma (epi-arachnoid)
  - variable shape, density, age
- Contusion (petechial)
  - Surface - cortex. coup/contra
  - Dark on GRE - CT "speckled"
- Axonal injury (DAI)
  - Deep - subcortical WM, corpus callosum and & basal ganglia